The residual excitation, or power which remains after excitation has ceased, is always of the same amount, 130.68, if that would have passed half the maximum; below that it bears a continually increasing ratio to the full power till it becomes two-thirds of it. If, while the magnet is in this state, a current that would of itself produce the same lift be passed, the effect is not doubled, but only increased by one-third. A negative current, if powerful, destroys this condition; if feeble, only lessens it.

The least current which he has tried, 0.0008, excites the magnet, and even changes its residual magnetism.

MONDAY, JUNE 28TH, 1852.

THOMAS ROMNEY ROBINSON, D. D., PRESIDENT, in the Chair.

MR. BERGIN read a paper on the illumination of objects in the microscope.

"All who are accustomed to the use of the microscope are necessarily aware of the vast improvements which have been effected within the last twenty years or little more. Prior to that, the compound microscope was almost worthless as an instrument of research, and inquiries as to minute structures were carried on by means of single lenses, or of combinations acting as single lenses: and when we look to the works remaining to us of the earlier microscopic observers, as Leeuwenhoek, Grew, Malpighi, and others, it is truly wonderful what they effected. However, the labour of such investigations with such means, or even with the jewel lenses of Pritchard, the doublets of Wollaston, or the triplets of Holland, was, as every one who has used them well knows, immense, and the injury to the sight caused by high powers unfortunately very great and enduring. All this, however, has been so amply and ably treated

by the writers of the last few years, that it is quite unnecessary now to go into the subject.

"It is scarcely requisite to say that, in the compound microscope, as in the telescope, the object-glass forms an ærial picture of the object under examination, which picture is examined by the eyepiece, the prominent difference being that with the telescope—the subject being remote, and the rays of light from it being approximately parallel, the image is formed nearly in the principal focus of the object-glass, and is smaller and proportionably more luminous than the object; while in the microscope, the object being near to the focal point of the object-glass, the image is formed in the conjugate focus, and is considerably larger and proportionably less luminous than the object itself. With both instruments the observer sees the object by the rays of light passing from it through the object-glass,—directly, if it be a luminous body,—by reflection at its surface from the source of light, if it be opaque,—or finally, if it be translucent, by transmission through its substance; but I think it will not be disputed that in all cases the origin of the light, which is the means of vision, is the points which are seen.

"Now, as the clearness of vision depends on the quantity of light which reaches the eye, it is manifestly important that the object-glass should have an aperture as large as possible; and here the modern object-glass, by correction of aberrations, spherical as well as chromatic, lends its wondrous aid.

"There is, however, one wide difference between the object-glasses of telescopes and of microscopes:—in both, the penetration, that is, the development of minute features depends on the quantity of light admitted, but in the former, which are corrected for incident light, nearly parallel the quantity depends on the diameter of the object-glass, irrespective of the distance of the object. In the microscopic the corrections are for divergent light, and as the quantity admitted with a given aperture is largely increased by bringing the lens closer to the origin of light, the correction of the aberrations for divergent pencils, especially those of such extraordinary divergence as are now used, complicates the problem immensely; and to this, no doubt, it is owing that so long an interval of time elapsed after the achromatic object-glass of the

telescope was perfected, before similar improvements were applied to the microscope. Indeed, notwithstanding the high mathematical genius of some, and the great practical skill of others, who attended to this subject, it was not till after the publication of Joseph Jackson Lyster's paper in the Philosophical Transactions for the year 1830, that the microscopist received with certainty a really efficient achromatic object-glass.

"Immediately after the publication of this important paper, the attention of our best opticians was directed to the microscope, and that race of improvement began which has led to such truly marvellous results.

"To be able to use a divergent pencil, of from 20° to 30°, was then thought to be a great triumph, but by successive steps our artists have now, for deep powers, mastered pencils far exceeding 100°. I have one by Nachet of Paris admitting 123°. I see Ross has accomplished an object-glass equivalent to one-fifth of an inch focus of 135° aperture; he has made several of one-twelfth focus amounting to 145°. Smith and Beck of London make objectives of very large angle; and in a recent number of Silliman's Journal it is announced that that truly worthy transatlantic competitor in this field, Spencer, has completed an object-glass of about one-twelfth inch focus, well utilizing a pencil of no less than 175°! Perhaps there has not been achieved any greater triumph of human skill, whether in reducing to practice the laws of light, or in moulding them to the further development of nature, than these object-glasses.

"But though so much has been accomplished, in the construction of the instrument, there probably remains much, not less important, respecting the arrangement of its illumination, as yet undiscovered; and as I believe every new fact in this department is valuable, I hope for the Academy's indulgence while submitting to it some of my results.

"For a very long period, much prior to the date of Mr. Lyster's paper, I have been a practitioner with the microscope. The instrument has always been a source of very high enjoyment to me, but as my avocations have, I regret to say, prevented my being a continuous investigator, I have wished, and, as far as I could, sought to be an improver. For the first few years I worked with the

single microscope in its various forms of single lenses, doublets, jewels, and triplets; it is therefore from personal experience I have referred to the fatigue and to the permanent injury of sight which they produce. My most constant object has been to improve, if I could, the preparation of the object for vision, especially what is technically called its illumination.

"When I commenced, the only mode of illumination in use was the light of the sky by day, or of a candle or lamp by night, reflected on the back of the object, and occasionally condensed by a lens, but the quantity of colour thus produced rendered this far from satisfactory. When Pritchard introduced his exceedingly commodious form of achromatic microscope, of one of which I soon became possessed, he gave the means of applying the direct light of a candle to the back of the object without the intervention of any mirror or condensing lens. This, besides being so exceedingly convenient and so free from trouble, was so great an improvement on the previous mode, that for a long time I rested satisfied with it. Meanwhile the improvements in achromatic object-glasses continued to progress, slowly, it is true, at first, still, very decidedly, and as from time to time objectives of larger aperture were made, the simple illumination became less and less efficient; recourse was then had to the so-called achromatic illumination: that is, forming by means of an achromatic lens an image of the luminary coincident with the object under examination; this acted very satisfactorily with some objects, but not so much so with others, but the image of the source of light always mingled inconveniently with the object under examination. Then came Read's dark ground illumination, in which, by means of a very oblique pencil of light, the object was shown luminous on the dark field of the instrument. It would however be tedious and useless to follow up minutely these slow advances; it is sufficient for my purpose to say that such as I have described was the state of the matter when I began to examine the subject.

"It appeared to me that, in transmitting light through a translucent object under the microscope, the image does not reach the eye by reason of the interception or coloration, by the parts of the object, of the light diverging from its original source; but that in

fact each part which so intercepts one and transmits another portion of the ray acts as an origin of light; and that from every point of the object this light diverges in every direction as from an original source. Now, the microscope is designed to give vision by light thus divergent; all else is an intruder, and does harm by causing fog and glare, which tend to obscure by overpowering the ærial picture.

"That this divergence of light from the surface after transmission through the substance does exist, admits, I think, of no doubt.

"Suppose a pencil of light passing through a dark space, and across the line of vision of a spectator, no impression whatever will be conveyed to his eye, save by reflection from particles floating in the atmosphere: let a translucent object of any kind be so placed that the pencil must pass through it, and immediately, no matter what may be the obliquity of direction from the eye of the observer to the anterior surface of the object, it will become visible.

"Taking it then, as established that the only rays of light which assist in forming the ærial picture on which microscopic vision depends are those which diverge from the object under observation, it follows that all other rays which enter the instrument, if they reach the eye, tend to confusion, and it becomes important to ascertain the best method of admitting such useless rays, when they cannot, or it is not desired that they should, be excluded. Without occupying time by discussing this point, I believe, as the result of consideration and experiment, that these rays ought to enter either so obliquely as to pass entirely across the axis, and thus not reach the eye at all, which is the condition of black ground illumination; or that they should be as nearly as possible parallel, in which case they come to a focus, close behind the object-glass, and, therefore, by their rapid divergence the greater part are thrown against the non-reflecting inside surface of the tube, and are thus absorbed, leaving but a small portion round the axis of the cone to reach the eye in a diffused state, giving a field more or less luminous according to the distance of their focus from the eye.

"Having satisfied myself of the truth of these premises, I sought for a construction which would realize them; first addressing myself to parallel light with a luminous field.

"To obtain a parallel beam of condensed light is very difficult,

if at all practicable, therefore we must seek for the nearest approximation to it. Single lenses of any kind form an image of the source of light, which, being coincident with the object under observation, mingles with it, and tends to confusion. I tried the image of a white disc of plaster of Paris, of a plate of unpolished silver, and other substances; but after a variety of trials, I ultimately found that the pencil emergent from the eye-piece of a telescope, when adjusted for distinct vision of a distant object, was the closest approximation I could obtain to that for which I sought; and accordingly I have adopted it with, as I conceive, very great advantage. My present arrangement consists of a disc of grey glass, strongly illuminated, an object-glass (so, for convenience, I call the lens nearest to the grey glass) and an eye-glass, that from which the illuminating beam passes to the object.

"These are each adjustable for distance, and should be so adjusted that, looking through the eye-glass you get a distinct image of the grey glass. The illuminator, thus arranged, is placed behind the object to be examined, this latter must then be adjusted for distinct vision through the microscope; a low power, say one inch, is convenient for this purpose; next, the illuminator must be so adjusted, as to distance behind the stage, that the circular spot of light which would be used, if a dynameter was applied to measure the power of the miniature telescope, shall be perfectly coincident with the object, which is then ready for examination with any power you please to apply.

"Such is the state in which I now use this illuminator, and I think I may say that all who have seen its performance, amongst whom our respected President has had the most frequent opportunities, will agree with me as to its superior efficiency.

"It is now some ten or twelve years since I first tried this arrangement; for a very long interval I was obliged to discontinue the use of the microscope, and it is only within a few months I have again returned to it. This much I feel it necessary to say in explanation of not having before this given any public description of the arrangement, and still more for not having further developed and improved it, in which respect much still remains to be done,—chiefly in determining the ratios of the lenses composing the instrument, in relation to the diameter of the illuminating

beam, which at present I incline to believe should just fill the field of view, especially for objectives of such large aperture as are now in use; as these, if the illuminating spot be larger than the field, collect too much of the light, which it is the object of the construction to get rid of. Whether this may be best effected by varying the distance between the lenses of the illuminator, or by stops or diaphragms external to the illuminating eye-glass, I have not yet tried, or whether there should be a variety of eye-glasses for the various powers.

"In my present illuminator the spot of light is about once and a half the diameter of the field of my inch power; yet with half-inch or quarter-inch objectives it gives such views of vegetable tissues, of fossil woods or teeth, and such like, as I have never otherwise seen, whether as regards distinctness and manifest truthfulness of details, or neatness of definition of the exterior edges; and with one-eighth objective of 108° aperture it, by direct light, distinctly shows both sets of lines on several of the more difficult test naviculæ, separating some of them into dots; but on this class of objects I have as yet done so little that I am unwilling to go into any details. Corroborative of the value of parallel light for illumination, I may here refer to a recent experiment. An achromatic microscope was directed to the minute but intensely brilliant image of the sun, formed by a solar microscope twelve or fourteen feet distant; here the rays could have had but a very few seconds of divergence, but the most minute details were shown with exquisite definition.

"With respect to the other mode of dealing with the useless rays before referred to, causing them to enter so obliquely as to pass entirely across the axis, and thus prevent their reaching the eye at all, I considered that it would be of value if not only the amount of obliquity but also the azimuth of the oblique ray in reference to the object could be varied by the observer, my impression being that in this manner many characteristic features of structure might be developed which with direct light could be seen but with difficulty, if at all: such as diseppiments in cellular tissues, elevations or depressions on the surface, or such like. I believed these would be rendered visible by the shadows they would cast. To effect this I at the time (ten or twelve years since) designed an instrument which would wholly revolve round the illuminated object as a cen-

tre of spherical motion. I showed models of this at the time to various friends, but I never proceeded to the construction. Since that time many exceedingly ingenious arrangements for so-called oblique illlumination have been brought forward; for instance, by Thomas Ross, Wenham, Shadbolt, Amici, Nachet, Nobert, Topping, and others, all of which are so fully described in Queckett's admirable work that it is unnecessary to do more than refer to the volume. With the exception, however, of Nachet's oblique prism, all these arrangements are in fact for direct illumination, stopping off the centre of the cone of rays before alluded to, and thus leaving the field of the instrument dark; little or no light reaching the eye but that coming from the object under examination; but as this light reaches the object equally from all azimuths, there are not any shadows the formation of which I conceive to be the distinguishing characteristic of oblique illumination.

"Among several of these illuminators, I procured during the last summer that which is known as the Paraboloid. This produces an annulus of light with a dark centre, but as it (like most of the others) throws the light obliquely but uniformly on every side of the object, there are, of course, no shadows. It occurred to me that by a slight addition this instrument offered the means of testing my old theory of oblique illumination with variable azimuth. The instrument consists of a solid paraboloid of glass, with a plane base, the focus near to the summit, which summit is ground away to form a spherical cavity, the centre of which coincides with the focus of the parabola; the middle of this spherical cavity is furnished with a dark stop; the action is, that parallel light falling perpendicularly on the base passes into the glass without refraction, and from the inner surface is reflected to the focus, which it reaches through the sides of the spherical cavity, also without refraction. The effect is, as I have before said, a speck of light at the focus, which is unfolded above or below into an annulus of light, with a dark centre; the object being adjusted perfectly coincident with this focal speck, is seen by the light radiating from its surface as before described, but the field is devoid of light.

"My addition to this is a glass prism producing two internal total reflections at right angles to each other; this prism is fixed to a disc of brass below the base of the paraboloid, and prevents any

light reaching this latter till after the two reflections, by which it is confined to one side of the base of the paraboloid and of course reaches the focus and the object at one side only, and by rotating the paraboloid (I believe it ought to be an ellipsoid) and prism to-together, this oblique illumination may be carried round the entire field of the microscope.

"This arrangement has realized my expectations. Having got it ready in October last, the first object on which I tried its capabilities was the Podura scale, an object which has been observed vastly more than any other test. I immediately saw appearances indicative of a structure entirely unknown before. In one azimuth of the light the scale appeared obscure and structureless, except that it was studded over with minute, nearly transparent dots, more resembling oil-glands in the leaves of the myrtaceæ than anything else with which I am acquainted.

"By rotating the light, faint shadows began to be visible in connexion with these dots, and when one-fourth of a revolution or thereabouts was completed, the dots had disappeared and the scale seemed to be covered, thatched as it were, with short, slender, cylindrical appendages; continuing the rotation in the same direction the scale gradually became obscure as before; these appendages ceased to be visible, and at the end of a second quarter revolution the luminous dots again appeared, more faint than at the opposite azimuth, still unquestionably there; completing the revolution, the same succession of appearances recurred until, on returning to the original azimuth, the dots re-appeared as luminous as at first.

"From frequent repetition of this observation, I am satisfied that this scale, instead of being covered with sculptured lines or folds, as was once believed, or with dark hairs, as figured by Queckett, is in reality covered with cylindrical appendages like quills, but which are either hollow or quite translucent through their axes.

"I infer this from finding that the several appearances are invariably and only seen with certain azimuths of the illumination; the bright dots when the light enters from the base of the scale; the fainter ones when it enters from the opposite extremity; and the cylindrical appearances when it enters at the side of the scale, in the longitudinal direction of which these appendages lie.

"Again, with the scale of the Lepisma, this is clearly seen to be

furnished with elevated ridges or lines running from one end to the other; and that the appearance of curved transverse lines, as seen by ordinary light, is caused by crenulations in the upper edge of these ridges. I might cite other cases, but these are enough to prove that this arrangement is capable of showing forms of structure which had not been previously recognised.

"I ought here to say I have since found that Nachet's oblique prism is capable of showing these peculiarities of structure, but I have been unable to recognise their existence by any of the other arrangements to which I have referred.

"I was able to exhibit these effects to our President on the evening of our first meeting this session, and soon after to other brothers of the microscope, including my friend Mr. Grubb. I mention this because I feel satisfaction in believing, as I do, that seeing this was not without its effect in leading to the exceedingly beautiful and efficient construction which he exhibited and explained to the Academy a short time since.

"I was unfortunately not here on that evening, but I have had various opportunities of using his contrivance, and gladly bear my testimony to the admirable arrangements he has effected for extending to the utmost limits the power of altering both the obliquity and azimuth of the light while in the act of observing, with the further advantage of being able, by means of graduated circles, to record with facility and precision all the adjustments by which any phenomenon has been observed.

"In conclusion, I wish it to be understood that the present communication is intended only to set forth the principles on which depend the proper illumination of objects under examination by the microscope; and that where I have described apparatus, I by no means consider it as perfect or as the best for the purpose, but I thought it right to state the means by which I tested the views put forward, hoping that others having more leisure and better qualified than I am will turn their attention to the subject, and give to the microscopist the best means of illuminating the objects of his study, thereby enabling him to reap the full benefit of the improvements which have been effected on the visual part of the instrument."